Video encoding

FIELD OF THE INVENTION

The invention relates to a video encoder and a method of predictively encoding images with reference to one reference image in a first prediction mode and to two reference images in a second prediction mode.

BACKGROUND OF THE INVENTION

Predictive video encoders as defined in the opening paragraph are generally known. For example, the MPEG video compression standard provides a first prediction mode in which images are encoded with reference to a previous image of the sequence. Thus, encoded images are referred to as P-pictures. The previous image may be an autonomously encoded I-picture or another P-picture. The MPEG standard also provides a second prediction mode in which images are encoded with reference to a previous image as well as a subsequent image of the sequence. Thus, encoded images are referred to as B-pictures. They are more efficiently encoded than P-pictures.

Motion compensation is usually applied to the respective reference images. To this end, the known video encoders include a motion estimation circuit which searches motion vectors representing motion between the input image and respective reference image(s). In the first (P) prediction mode, the motion estimation circuit is used for searching forward motion vectors representing motion between input image and previous image. In the second (B) prediction mode, the motion estimation circuit is used in a first interval of the frame encoding period for searching forward motion vectors representing motion between input image and previous image, and in a second interval of said frame encoding period for searching backward motion vectors representing motion between input image and subsequent image.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to further improve the video encoder.

To this end, the video encoder in accordance with the invention is characterized in that the motion estimation circuit is arranged to use the first interval of the

frame encoding period in the first (P) prediction mode to search motion vectors representing motion between an input image and said one reference image, and to use the second interval of said frame encoding period to refine the motion vectors found in the first interval.

The motion estimation circuit of the prior-art video encoder executes the motion vector search twice within a frame encoding period in the second (B) prediction mode. One run, or pass, of the search process is used to generate the forward motion vectors, another run is used to generate the backward motion vectors. In the first (P) prediction mode, forward motion vectors need to be searched only. The invention is based on the recognition that the motion estimator can be used a second time in the P-prediction mode so as to further refine the search for forward motion vectors. It is achieved with the invention that the motion vectors associated with P-pictures are more precise than the motion vectors associated with B-pictures. This is attractive because P-pictures are generally wider apart from each other than B-pictures.

In an embodiment of the encoder, in which the motion estimation circuit is arranged to search a motion vector from among a plurality of given candidate motion vectors, said candidate motion vectors in the second interval are formed by predetermined variations of the motion vector found in the first interval.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 shows a schematic diagram of a video encoder in accordance with the invention.

Fig. 2 shows a diagram to illustrate a prior-art operation of the video encoder.

Figs. 3 and 4A-4C show diagrams to illustrate the operation of the video encoder in accordance with the invention.

DESCRIPTION OF EMBODIMENTS

The invention will now be described with reference to an MPEG video encoder. However, the invention is not restricted to encoders complying with the MPEG standard. Fig. 1 shows a schematic diagram of the encoder in accordance with the invention. The general layout is known per se in the art. The encoder comprises a subtracter **1**, an orthogonal transform (e.g. DCT) circuit **2**, a quantizer **3**, a variable-length encoder **4**, an inverse quantizer **5**, an inverse transform circuit **6**, an adder **7**, a memory unit **8**, and a motion estimation and compensation circuit **9**.

The memory unit **8** includes memories **81a** and **81b** each having the capacity for storing a reference image. The memory unit further includes two switches **83** and **84**. Switch **83** controls which one of the memories is read by the motion estimator. Switch **84** controls in which one of the memories the encoded image is stored. The switches are implemented as software-controlled memory-addressing operations in practical embodiments of the encoder.

As is generally known in the art of video coding, I-pictures are autonomously encoded without reference to a previously encoded image. Subtracter **1** is inoperative. The I-picture is locally decoded and stored in one of the memories **81a** or **81b**. P-pictures and B-pictures are predictively encoded with reference to a prediction image. To this end, the subtracter **1** subtracts a motion-compensated prediction image X_p from the input image X_i, so that the difference is encoded and transmitted. Adder **7** adds the locally decoded P-picture to the prediction image so as to update the stored reference image.

Fig. 2 shows a timing diagram to summarize a prior-art operation of the encoder. The diagram shows the positions of switches **83** and **84** during consecutive frame periods for encoding an IBBPBBP.. sequence. The frames are identified by encoding type (I, B, P) and display order. I1 is the first frame, B2 is the second frame, B3 is the third frame, P4 is the fifth frame, etc.

More particularly, Fig. 2 shows that the I-picture (I1) is written into memory **81a** (switch **84** in position a). The first P-picture (P4) is predictively encoded with reference to the stored I-picture (switch **83** in position a), and written into memory **81b** (switch **84** in position b). The subsequent P-pictures (P7, P10, ..) are alternately read from and written into the memories **81a** and **81b**.

B-pictures are encoded with reference to a previous and a subsequent I or P-picture. Note that this requires the encoding order of images to be different from the display order. Circuitry therefor is known in the art and not shown in the Figure. The motion estimation and compensation circuit **9** accesses both memories **81a** and **81b** to generate forward motion vectors (referring to the previous image) and backward motion vectors (referring to the subsequent image). To this end, the switch **83** switches between position a and position b. Said switching is shown on a frame-by-frame basis for simplicity. In practice, the switching is done at the macroblock level.

The motion estimation circuit executes a given motion vector search process. Said process requires reading of the respective memory for a given number of times, say N. As Fig. 2 clarifies, encoding of B-pictures requires 2N memory accesses per frame period.

The same vector search process requires N memory accesses per frame in the P-encoding mode, whereas 2N accesses are available. This recognition is exploited by the invention. To this end, the motion vector search process is carried out in two passes for P-pictures. In the first pass, the motion vectors are found with a 'standard' precision. In the second pass, the same process is carried out to further refine the accuracy of the motion vectors that were found in the first pass. The two-pass operation is illustrated in Fig. 3, the refining pass being denoted by a' or b', as the case may be. Note again that the two-pass operation is carried out in practice on a macroblock-by-macroblock basis.

Figs. 4A-4C show parts of an image to further illustrate the two-pass motion estimation process. Fig. 4A shows a current image **400** to be predictively (P) encoded. The image is divided into macroblocks. A current macroblock to be encoded includes an object **401**. Reference numerals **41, 42, 43** and **44** denote motion vectors already found during encoding of neighboring macroblocks. Figs. 4B and 4C show the previous I or P-picture **402** stored in one of the memories **81a** or **81b**, as the case may be. In the previous reference image, the object (now denoted **403**) is at a different position and has a slightly different shape. In this example, the motion estimator searches the best motion vector from among a number of candidate motion vectors. Various strategies for selecting suitable candidate motion vectors are known in the art. It is here assumed that the motion vectors denoted **41, 42, 43** and **44** in Fig. 4A are among the candidate motion vectors for the current macroblock. Fig. 4B shows the result of the first motion vector search process pass. It appears that candidate motion vector **43** provides the best match between the current macroblock of the input image and an equally sized block **404** of the reference image.

In the second pass, the same search algorithm is applied with different candidate vectors. More particularly, the motion vector found in the first pass is one candidate motion vector. Other candidate vectors are further refinements thereof. This is illustrated in Fig. 4C, where **43** is the motion vector found in the first pass and eight dots **45** represent end points of new candidate motion vectors. They differ from motion vector **43** by one (or one-half) pixel. The same search algorithm is now carried out with the new candidate vectors. It appears in this example that block **405** best resembles the current macroblock. Accordingly, motion vector **46** is the motion vector which is used for producing the motion-compensated prediction image X_p. The two-pass operation for P-pictures is particularly attractive because it provides more accurate motion vectors for images that are wider apart than B-pictures.

The invention can be summarized as follows. A conventional MPEG video encoder searches forward motion vectors with respect to a previous image and backward motion vectors with respect to a subsequent image in order to provide a motion-compensated prediction image for encoding B-pictures. This requires 2N accesses to the memory in which said images are stored. Searching the motion vectors for P-pictures requires N memory accesses. The invention uses the spare capacity by running a two-pass motion vector search in the P-coding mode. In the second pass, the precision of the motion vectors found in the first pass is further refined. This provides more accurate motion vectors for P-pictures.